Antenna Techniques to Reduce Airborne User Dynamic Range Requirements

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Presentation Overview

- **Introduction and Background**

- **Goals and Expected Outcomes**

- **Siting Investigation**

- **Future Stages**

- **Conclusions**

Introduction

- **Research is being conducted to continue to minimize errors in differential GPS.**

- **This presentation will discuss ways to minimize the receiver dynamic range requirements when used with pseudolite transmissions.**

- **Software techniques are possible, but antenna techniques have been chosen for this investigation.**

Receiver Dynamic Range

- **Dynamic Range is a loose definition but will be referred to as the range of power levels that can go into a receiver and still get an accurate output. This is highly dependant upon the receiver design.**

- **It is limited by receiver components such as AGC, A/D converter, RF front end.**

- **Typical GPS receivers have a range of 30 dB before the A/D saturates.**

- **It is still possible to get linear output up to 45 dB while in saturation.**

Exceeding the DR

- **Biases can be meter level errors.**

- **3 - 3.5 meter biases are possible when using a wideband code.**

- **9 meter biases are possible when using a narrowband code.**

- **Along with ground multipath, this can be one of the largest error sources in differential GPS.**

Motivation for Research

- **Optimize APL Transmission Characteristics.**

- **Dynamic Range Requirement Reduction through Antenna Siting.**

- **Dynamic Range Requirement Reduction through Antenna Pattern Design.**

- **These Techniques Serve to Eliminate Potential GPS Pseudorange Biases as a Result of Receiver Saturation.**

Motivation for Research Cont'd

- **Prototype Local Area Augmentation System (LAAS) currently uses two antennas to provide full hemispherical reception of GPS navigation information.**
    - » **Vertical Linear Array - Multipath Limiting Antenna (MLA)**
    - » **Helibowl - High Zenith Antenna (HZA)**

- **A single antenna design could reduce the cost and complexity of the system.**
    - » **Eliminate a second GPS receiver**
    - » **Smaller and lower cost than existing equipment**
    - » **Could be used for pseudolite transmission while still offering an acceptable desired/undesired (D/U) ratio**

Goals and Expected Outcomes

- **Develop a simulation to model propagation characteristics of the existing antenna system.**

- **Build an understanding of the ideal antenna location and the ideal antenna pattern.**

- **Design an omnidirectional antenna with the desired characteristics in elevation.**

- **Design verification through data collection at an antenna test range and/or by collection of real GPS data.**

Siting Investigation

- **A simulation model has been completed in Matlab.**

  - » **Based on Friis transmission equation.**

  - » **Real data was used to increase the fidelity of the model.**

- **A Model was then used in a siting study to determine the effect of moving the airport pseudolite (APL) antenna on receiver dynamic range.**

  - » **Changed the *Offset* (Distance to the side of the runway) - 100 ft, 500 ft, and 1000 ft**

  - » **Changed the *Advance* (Distance in front of the runway) - 100 ft, 500 ft, and 1000 ft**

- **Surface plots were created showing the received power as a function of APL location.**

APL Location Variation
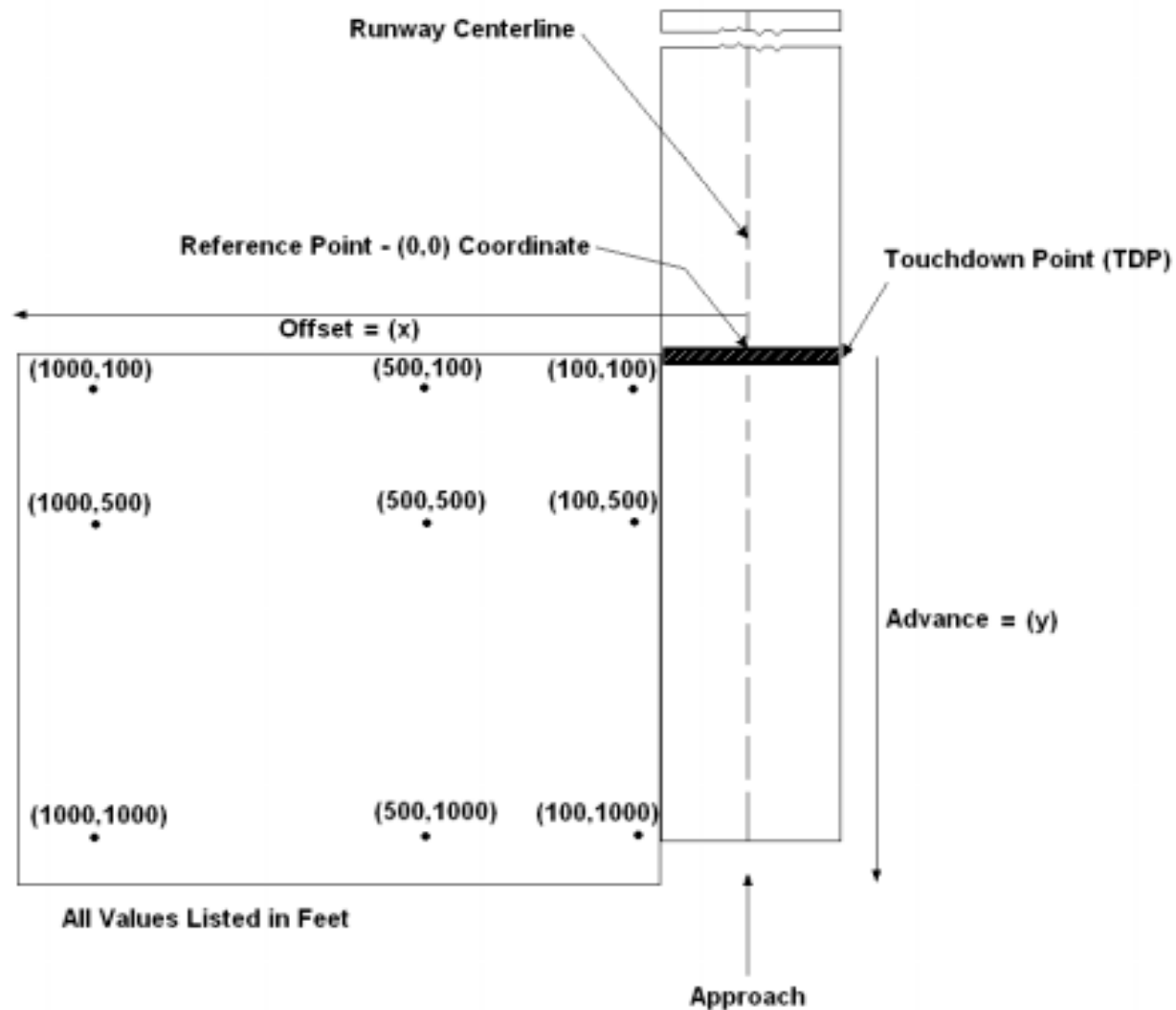
Simulation Layout
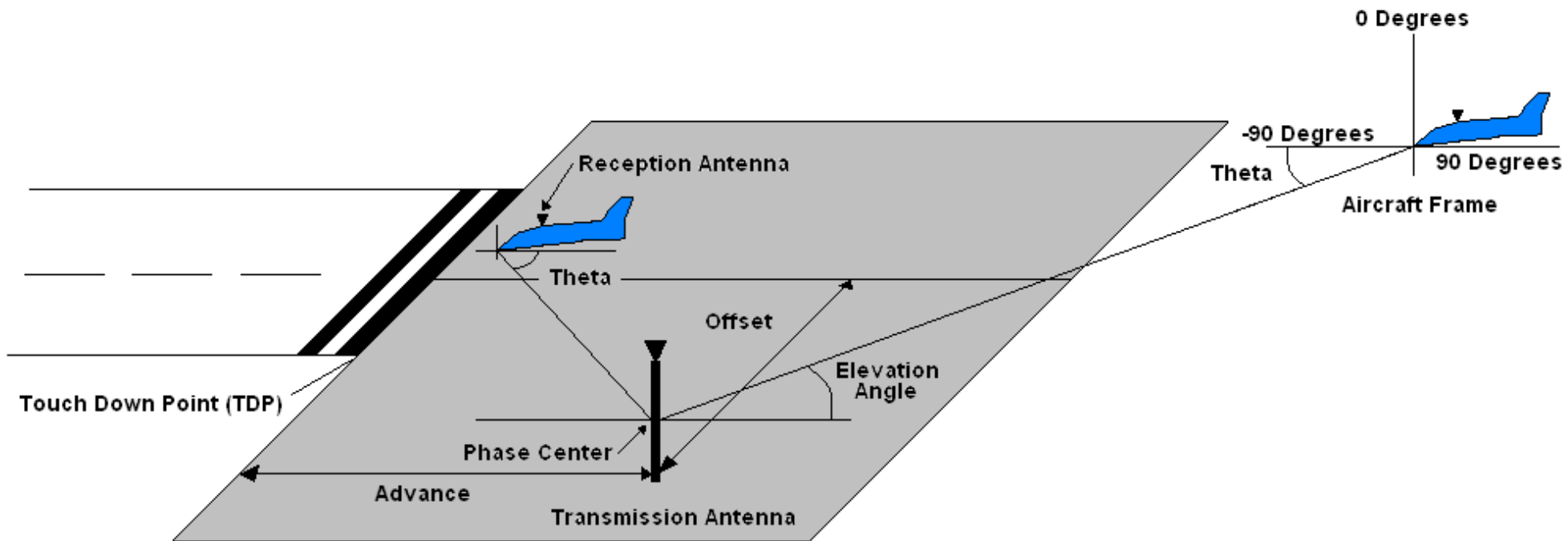
# The Matlab Simulation

- **Friis Transmission Equation**

$$P_r = \left(\frac{\lambda}{4 \cdot \pi \cdot R} \right)^2 \cdot G_t \cdot G_r \cdot P_t$$

» λ - Wavelength [meters]

» R - Range Between Antennas [meters]

» Pr - Received Power [watts]

» Pt - Transmitted Power [watts]

» Gt - Transmitting Antenna Gain [unitless]
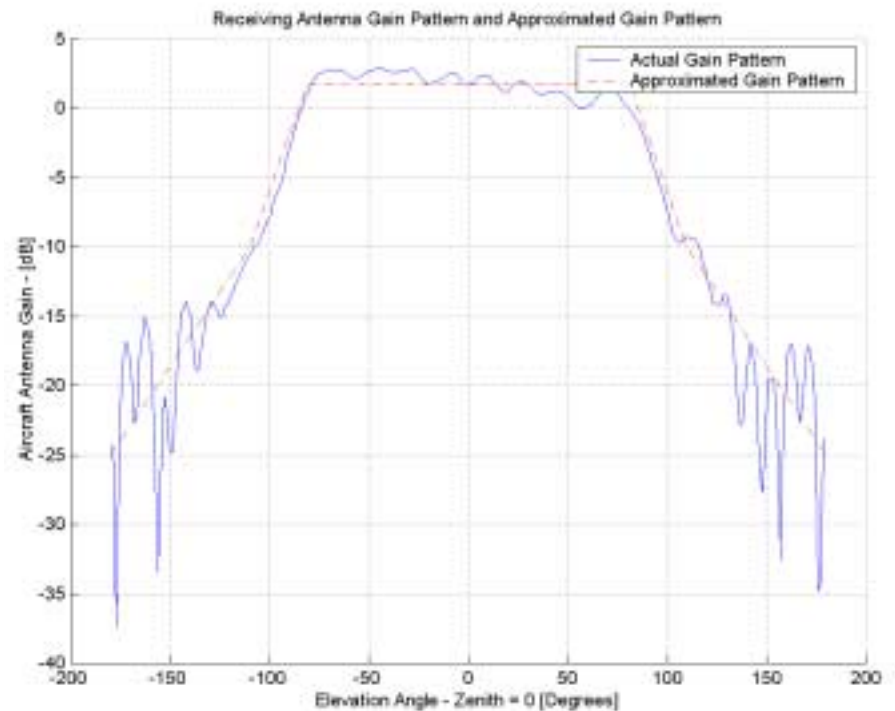
» Gr - Receiving Antenna Gain [unitless]

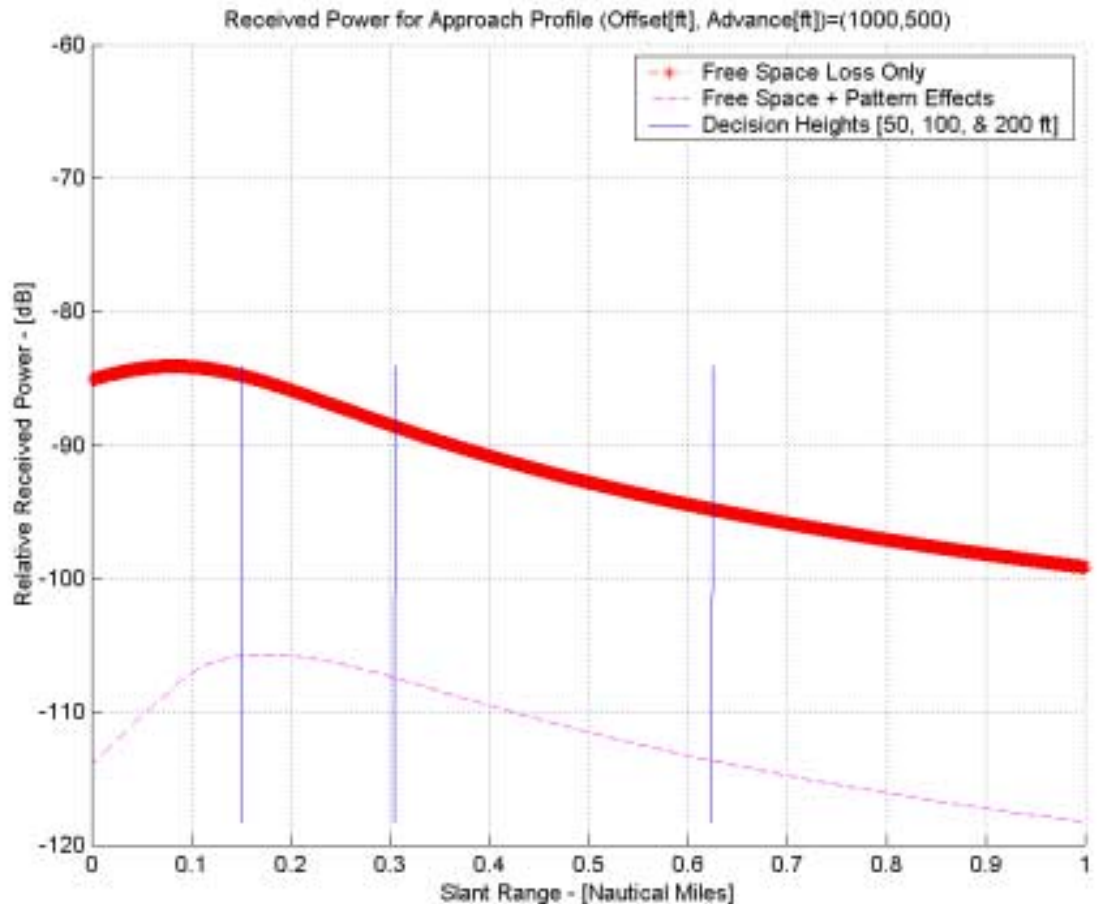# Antenna Gains Used in Simulations

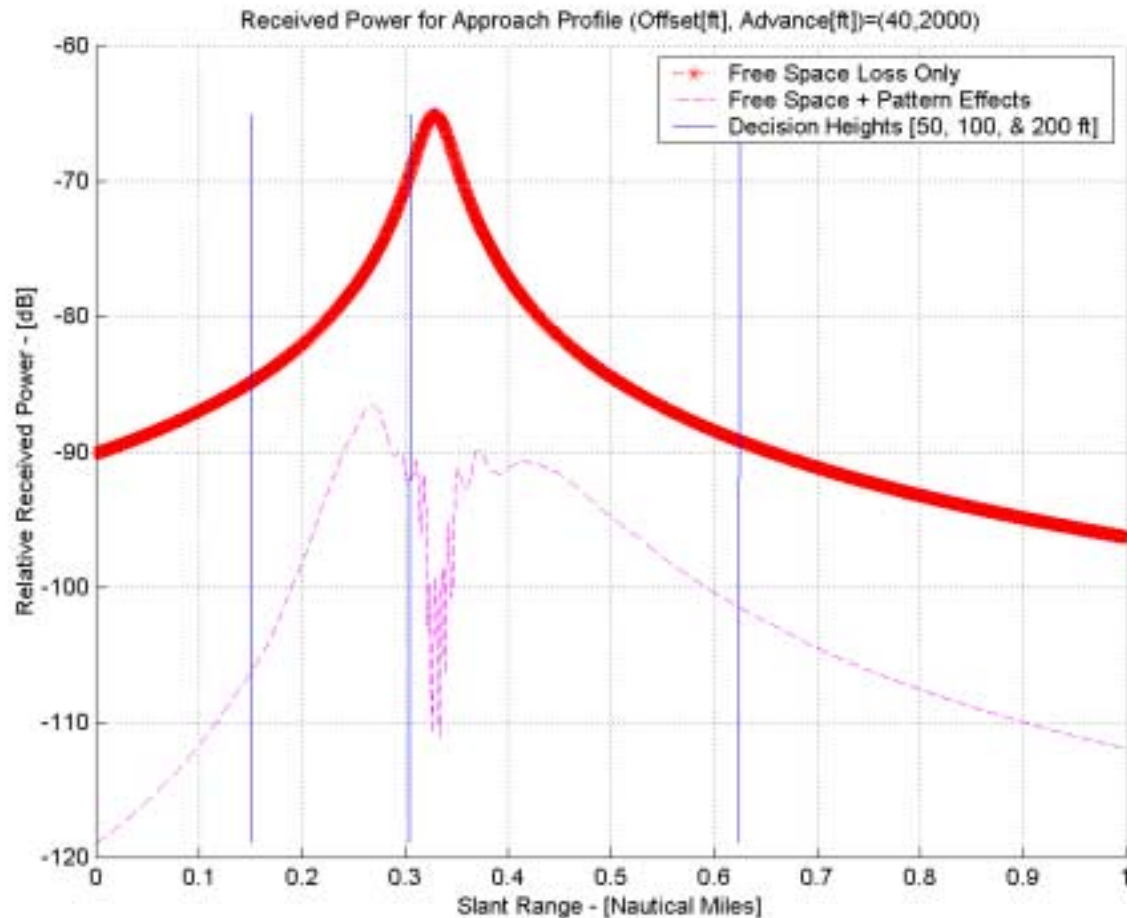**Ground Station MLA - P_t**

Aircraft Antenna - P_r

Transmitting Antenna Gain Pattern

Receiving Antenna Gain Pattern and Approximated Gain Pattern
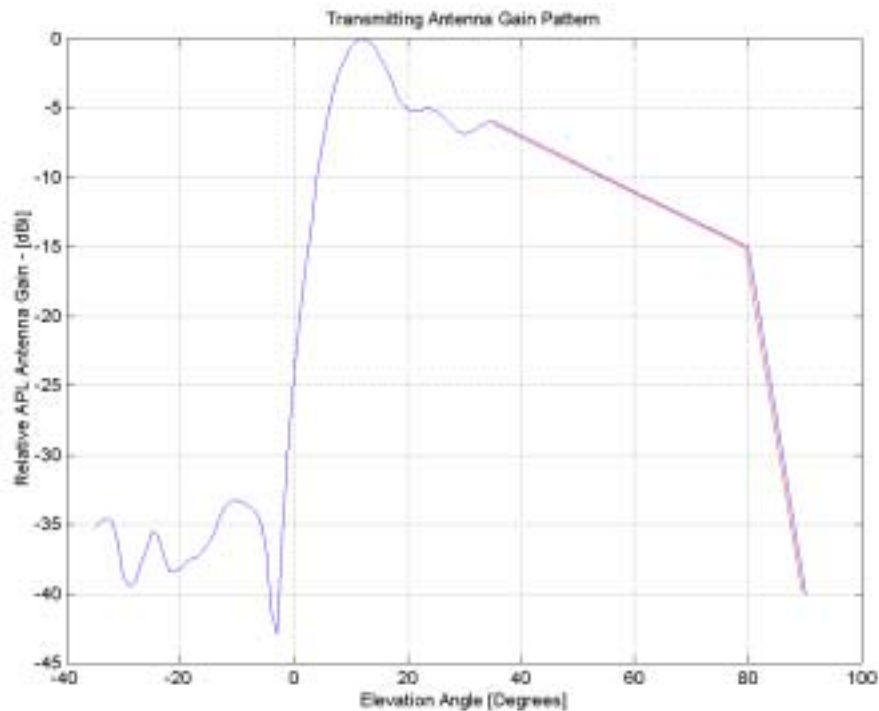
Power Profile Analysis

- **What to Look for:**
  - » **Overall flatness of the curve**
  - » **Location of the peak**
  - » **Distortions in the curve**
  - » **Differences between the two curves**

Received Power for Approach Profile (Offset[ft], Advance[ft])=(1000,500)

Legend:
- ---*--- Free Space Loss Only
- ------ Free Space + Pattern Effects
- ------ Decision Heights [50, 100, & 200 ft]

Y-axis: Relative Received Power – [dB]
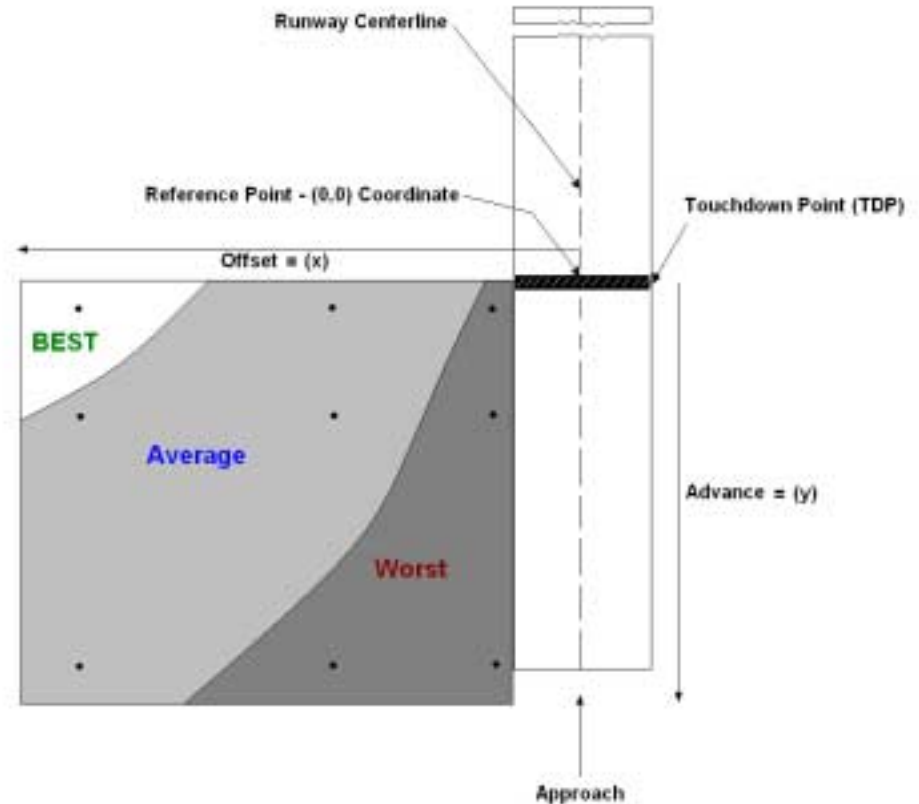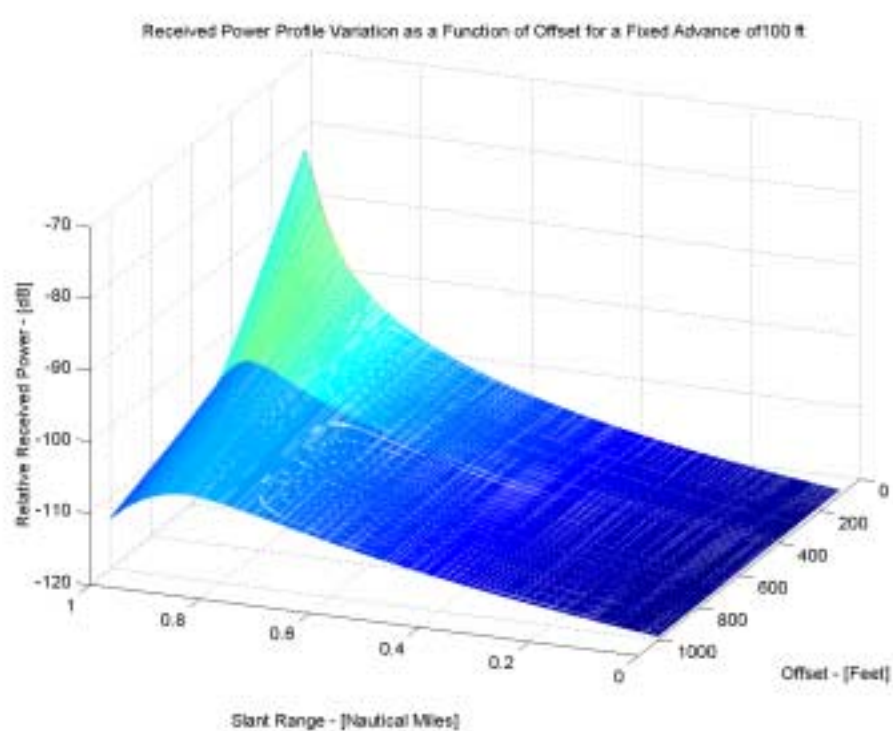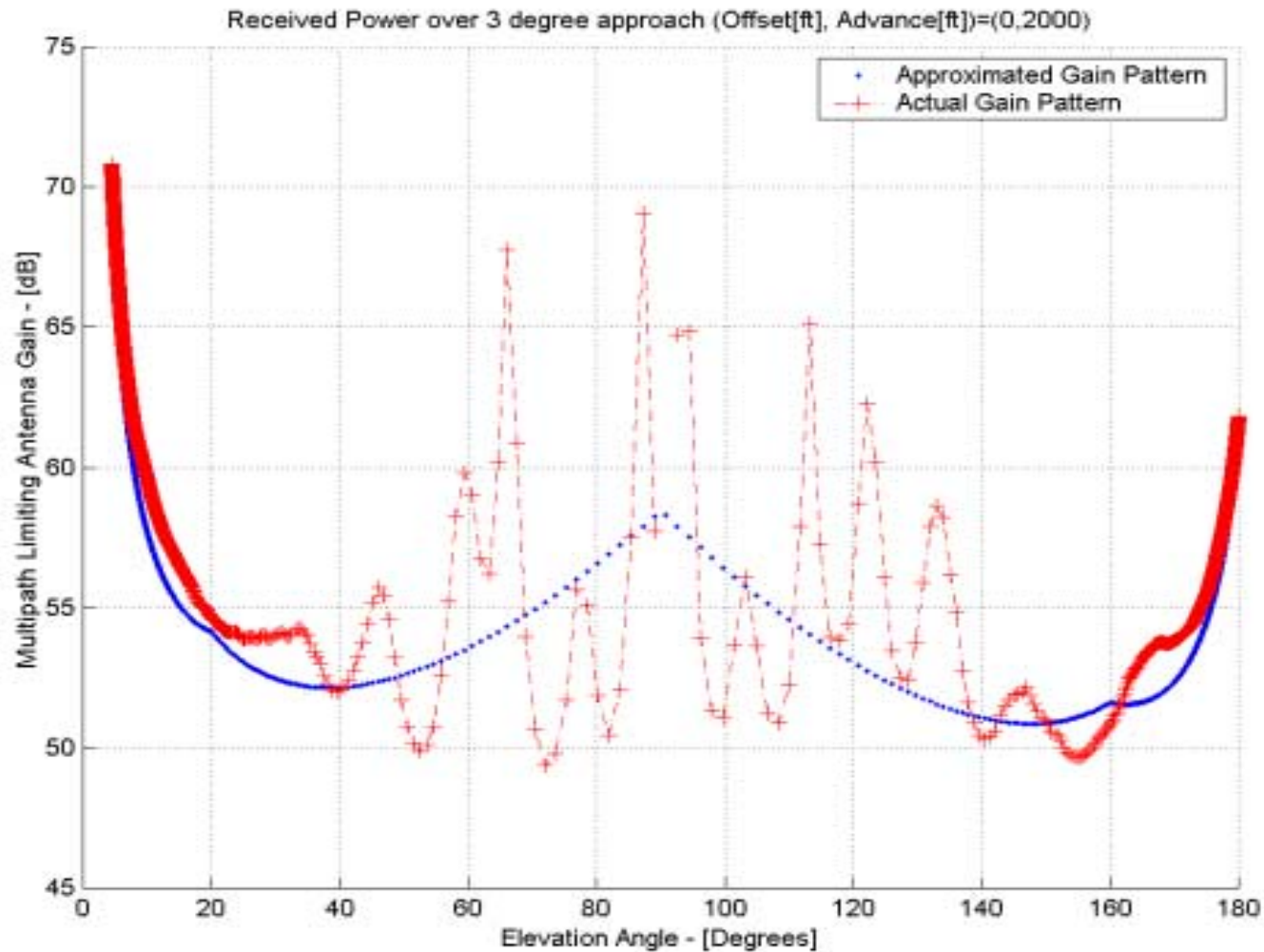X-axis: Slant Range – [Nautical Miles]

Received Power Profiles

Received Power Profile For Current LAAS Site at UNI

Best APL Antenna Locations

Synthesized Transmission Antenna Gain

Received Power over 3 degree approach (Offset[ft], Advance[ft])=(0,2000)

Avionics Engineering Center

Future Stages

- **Synthesize complete antenna pattern.**

- **Produce NEC models to create desired antenna pattern.**

- **Fabricate an antenna based upon the synthesized antenna pattern.**

- **Conduct tests at an antenna test range facility.**

Conclusions

- **Exceeding the dynamic range of a receiver can lead to biases in the GPS navigation solution.**

- **This problem can be reduced or eliminated by using antenna siting and synthesis techniques.**

- **Some antenna sites are better suited for airport pseudolite transmission than others.**

- **An antenna with a gain pattern tailored to reducing dynamic range requirements can also eliminate the bias problem.**